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**UTILITY  
PATENT TRANSMITTAL**

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No. 862.C1856

First Named Inventor or Application Identifier

HIROSHI TANAKA

Express Mail Label No.

**APPLICATION ELEMENTS**

See MPEP chapter 600 concerning utility patent application contents.

1. ☒ Fee Transmittal Form  
(Submit an original, and a duplicate for fee processing)
2. ☒ Specification Total Pages
3. ☒ Drawing(s) (35 USC 113) Total Sheets
4. ☒ Oath or Declaration Total Pages
- a. ☒ Newly executed (original or copy)
- b. ☐ Unexecuted for information purposes
- c. ☐ Copy from a prior application (37 CFR 1.63(d))  
(for continuation/divisional with Box 17 completed)  
[Note Box 5 below]
- i. ☐ **DELETION OF INVENTOR(S)**  
Signed Statement attached deleting  
inventor(s) named in the prior application, see  
37 CFR 1.63(d)(2) and 1.13(b).
5. ☐ Incorporation By Reference (useable if Box 4c is checked)  
The entire disclosure of the prior application, from which a copy of  
the oath or declaration is supplied under Box 4c, is considered as  
being part of the disclosure of the accompanying application and is  
hereby incorporated by reference therein.

**ADDRESS TO:**Assistant Commissioner for Patents  
Box Patent Application  
Washington, DC 20231

6. ☐ Microfiche Computer Program (Appendix)
7. Nucleotide and/or Amino Acid Sequence Submission  
(if applicable, all necessary)
- a. ☐ Computer Readable Copy
- b. ☐ Paper Copy (identical to computer copy)
- c. ☐ Statement verifying identity of above copies

**ACCOMPANYING APPLICATION PARTS**

8. ☒ Assignment Papers (cover sheet & document(s))
9. ☐ 37 CFR 3.73(b) Statement (when there is an assignee) ☐ Power of Attorney
10. ☐ English Translation Document (if applicable)
11. ☐ Information Disclosure Statement (IDS)/PTO-1449 ☐ Copies of IDS Citations
12. ☐ Preliminary Amendment
13. ☒ Return Receipt Postcard (MPEP 503)  
(Should be specifically itemized)
14. ☐ Small Entity ☐ Statement filed in prior application  
Statement(s) Status still proper and desired
15. ☐ Certified Copy of Priority Document(s)  
(If foreign priority is claimed)
16. ☐ Other: \_\_\_\_\_

**17. If a CONTINUING APPLICATION, check appropriate box and supply the requisite information:**☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No. \_\_\_\_\_**18. CORRESPONDENCE ADDRESS**☒ Customer Number or Bar Code Label

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CLAIMS	(1) FOR	(2) NUMBER FILED	(3) NUMBER EXTRA	(4) RATE	(5) CALCULATIONS
	TOTAL CLAIMS (37 CFR 1.16(c))	36-20 =	16	X \$ 18.00 =	\$ 288.00
	INDEPENDENT CLAIMS (37 cfr 1.16(b))	6-3 =	3	X \$ 78.00 =	\$ 234.00
	MULTIPLE DEPENDENT CLAIMS (if applicable) (37 CFR 1.16(d))			\$ 260.00 =	\$ 0.00
				BASIC FEE (37 CFR 1.16(a))	\$ 690.00
			Total of above Calculations = \$1212.00		
	Reduction by 50% for filing by small entity (Note 37 CFR 1.9, 1.27, 1.28).				
	TOTAL = \$1212.00				

19. Small entity status

- a. ☐ A Small entity statement is enclosed
- b. ☐ A small entity statement was filed in the prior nonprovisional application and such status is still proper and desired.
- c. ☐ Is no longer claimed.

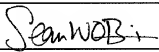
20. ☒ A check in the amount of \$ 1212.00 to cover the filing fee is enclosed.

21. ☒ A check in the amount of \$ 40.00 to cover the recordal fee is enclosed.

22. The Commissioner is hereby authorized to credit overpayments or charge the following fees to Deposit Account No. 06-1205:

- a. ☒ Fees required under 37 CFR 1.16.
- b. ☐ Fees required under 37 CFR 1.17.
- c. ☐ Fees required under 37 CFR 1.18.

**SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT REQUIRED**

NAME	Sean W. O'Brien - Reg. No. 37,689
SIGNATURE	
DATE	March 8, 2000

SEW\SWO\cmv

TITLE OF THE INVENTION  
POSITION DETECTION APPARATUS AND  
EXPOSURE APPARATUS

5 FIELD OF THE INVENTION

The present invention relates to a position detection apparatus for detecting the position of a mark on an object and an exposure apparatus using the position detection apparatus.

10

BACKGROUND OF THE INVENTION

In an exposure apparatus for manufacturing, e.g., semiconductor devices that are increasingly shrinking in their feature sizes, before a reticle pattern is projected on a wafer by exposure, the wafer and reticle are aligned.

Alignment includes two techniques: pre-alignment and fine alignment. In pre-alignment, a feed shift amount generated when a wafer is loaded from a wafer conveyor apparatus onto a wafer chuck on a stage in a semiconductor exposure apparatus is detected, and the wafer is coarsely aligned within an accuracy with which subsequent fine alignment can be normally processed. In fine alignment, the position of the wafer placed on the wafer chuck on the stage is accurately measured, and the wafer and reticle are precisely aligned such that the alignment error between the wafer and reticle fall within the allowable range. The

pre-alignment accuracy is, e.g., about 3  $\mu\text{m}$ . The fine alignment accuracy is, e.g., 80 nm or less for a 64 MDRAM although it changes depending on the requirement for wafer work accuracy.

- 5           Pre-alignment requires detection in a very wide range because the wafer feed shift generated when the conveyor apparatus feeds a wafer onto the chuck is detected, as described above. The detection range is generally about 500  $\mu\text{m}$  squared. As a method of detecting the X- and
- 10 Y-coordinates of one mark and performing pre-alignment, pattern matching is often used.

- Pattern matching is roughly classified into two techniques. In one technique, a mark image is binarized, the binary image is matched with a predetermined template,
- 15 and a position at which the binary image and template have the highest correlation is determined as a mark position. In the other technique, the correlation between a mark image that remains a grayscale image and a template having grayscale information is calculated. As the latter method,
- 20 normalization correlation is often used.

- In pre-alignment, the mark to be used must be small although the detection range is very wide. This is because as a pattern other than a semiconductor element is used as a mark, the mark is preferably as small as possible to make
- 25 the semiconductor element area as large as possible. Hence, the mark is often laid out in a region that is not used as

an element, e.g., on a scribing line. The mark size is therefore limited by the scribing line width.

The scribing line width is becoming narrower year by year because of the high efficiency of semiconductor manufacturing and improved work accuracy in recent years. Currently, the scribing line width is as small as 100  $\mu\text{m}$  or less, and accordingly, the mark size is also 60  $\mu\text{m}$  or less.

On the other hand, to manufacture a semiconductor device with high density, a wafer is processed through new processes.

A problem associated with pre-alignment mark detection will be described with reference to Figs. 6A to 6H. Fig. 6A shows a layout in which a semiconductor element pattern is adjacent outside a cross-shaped mark 100, in which a portion wide long in the horizontal direction is a signal detection region. Figs. 6B and 6D show detection signal waveforms, and Figs. 6C and 6E show the wafer sectional structures corresponding to the signals shown in Figs. 6B and 6D. Fig. 6F also shows the cross-shaped detection mark 100. Fig. 6G shows the detection signal waveform. Fig. 6H shows the wafer sectional structure corresponding to Fig. 6G.

Fig. 6E shows the sectional structure of the mark after an ultra low step process. Fig. 6H shows the sectional structure of the mark after a CMP process. In

these examples, it is difficult to detect the pre-alignment mark.

In pre-alignment, generally, a mark once formed is continuously used for position detection even in the subsequent processes. However, as layers are deposited on the mark, it gradually becomes hard to observe the mark. In the sectional structure shown in Fig. 6E, since a mark having low reflectivity and small step difference is present in a material having high reflectivity and large step difference, the mark can hardly be detected. In addition, since various layers are deposited on the mark, the image obtained by reading the mark may have low contrast and much noise.

The examples shown in Figs. 6A to 6H suggest that along with the progress in the technique of manufacturing a semiconductor device with high density, processes that make detection of a pre-alignment mark present in a wide detection range by the conventional pattern matching hard have emerged and they present problem.

For example, as shown in Fig. 6E, when the mark has a small step difference although the peripheral pattern has a large step difference and high reflectivity, an image signal shown in Fig. 6D is obtained. The image signal shown in Fig. 6D is a signal in the region win shown in Fig. 6A, which is obtained by sensing the pre-alignment mark 100 irradiated by dark field illumination. The ordinate

represents a video signal voltage, and the abscissa represents a coordinate. When the signal is binarized using a predetermined threshold value, the mark disappears because the signal level of the mark portion is low. For  
5 this reason, the mark cannot be recognized by template matching.

Even with normalization correlation which is known as a detection method for a grayscale image, it is also difficult to detect a mark in an image with small step  
10 difference and low contrast or a noisy image. Especially, the detection rate of normalization correlation tends to be low when the influence of noise is large, or mark defects occur in the wafer process. Additionally, the process time is long because of the complex calculation method.

15 Various approximation calculations have also been examined to solve the above problem. However, the problem of low detection rate for a low-contrast image remains unsolved.

Another well-known mark detection method is the  
20 vector correlation method (Video Information 1992/2). The vector correlation method can obtain a high detection rate even when the mark image has noise or the mark has a defect. In the vector correlation method, attribute information representing the feature of edge information is extracted  
25 together with the edge of the mark. With this correlation calculation method, the extracted feature is compared with

a template to detect the mark position.

In the vector correlation method, a high-contrast mark and low-contrast mark cannot be detected using the same parameter in extracting the edge information of the marks.

5 Hence, the edge extraction parameter need be tuned.

#### SUMMARY OF THE INVENTION

The present invention has been made in consideration of the above situation, and has as its object to stably  
10 detect the position of a mark even in a mark image that is difficult to detect, e.g., a low-contrast mark image, a noisy mark image, or a mark image whose mark has a defect generated in the wafer process. Especially in association with the vector correlation method, it is another object  
15 of the present invention to optimize a mark detection method in accordance with a mark image in extracting information related to an edge and stably detect the mark position and, more specifically, to cope with any mark image by self  
learning and stably detect the mark position.

20 According to the first aspect of the present invention, there is provided a position detection apparatus for detecting a position of a mark on an object, comprising an extraction section for observing the mark and extracting a plurality of edge information of the mark in  
25 correspondence with attribute information representing features of the edge information, respectively, a position



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determination section for comparing each edge information with one of a plurality of templates, which is specified by attribute information corresponding to the edge information and evaluating a plurality of comparison results obtained by comparison to determine the position of the mark, and a control section for changing at least one of an extraction rule in the extraction section and an evaluation rule in the position determination section on the basis of the plurality of comparison results by the position determination section and causing the extraction section and the position determination section to execute processing again.

In the position detection apparatus according to the first aspect of the present invention, each attribute information preferably represents an edge portion of the mark, which is associated with the corresponding edge information. In addition, each attribute information preferably represents one of a plurality of extraction conditions under which the corresponding edge information is extracted.

In the position detection apparatus according to the first aspect of the present invention, preferably the extraction section extracts, as each edge information, information representing an edge position shifted from an actual edge position of the mark by a predetermined distance in one of a plurality of predetermined directions, and each

attribute information represents a direction in which an edge position associated with the corresponding edge information shifted from the actual edge position of the mark by the predetermined distance.

5           In the position detection apparatus according to the first aspect of the present invention, the extraction section preferably comprises an image sensing section for sensing an image of the mark, a differential processing section for differentiating the mark image as an image  
10   sensing result, and an edge information generation section for processing the differential result to generate the edge information corresponding to the attribute information.

          Preferably, the differential processing section calculates a change rate of an image signal of the mark image  
15   along at least two directions of the mark image, and each attribute information is associated with one of the at least two directions.

          Alternatively, each attribute information is preferably associated with a sign of the differential  
20   result by the differential processing section.

          Alternatively, preferably the differential processing section calculates a change rate of an image signal of the mark image across the mark image along row and column directions of the mark image, and each attribute  
25   information is associated with one of the row and column directions and the differential result by the differential

processing section.

In the position detection apparatus according to the first aspect of the present invention, each template preferably includes, as information to be compared with the edge information, position information of a plurality of points defining a corresponding edge.

In the position detection apparatus according to the first aspect of the present invention, the extraction section preferably performs noise removal processing for an observation result of the mark and then executes edge information extraction.

In the position detection apparatus according to the first aspect of the present invention, the extraction section preferably increases a line width associated with the extracted edge information.

In the position detection apparatus according to the first aspect of the present invention, the extraction rule and/or the evaluation rule determined by the control section is preferably stored in a memory and used as a base for processing to be executed later.

In the position detection apparatus according to the first aspect of the present invention, the extraction section preferably observes the mark under dark field illumination.

According to the second aspect of the present invention, there is provided a position detection apparatus

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for detecting a position of a mark on an object, comprising  
an extraction section for observing the mark and extracting  
edge information of the mark, a position determination  
section for comparing the edge information with a template  
5 and evaluating a comparison result to determine the  
position of the mark, and a control section for changing  
at least one of an extraction rule in the extraction section  
and an evaluation rule in the position determination  
section on the basis of the evaluation result by the  
10 position determination section and causing the extraction  
section and the position determination section to execute  
processing again.

According to the third aspect of the present  
invention, there is provided an exposure apparatus  
15 comprising a projection optical system for projecting a  
pattern onto a substrate, a chuck on which the substrate  
is placed, and a position detection section for detecting  
a position of a mark on the substrate placed on the chuck,  
wherein the substrate is aligned on the basis of a detection  
20 result by the position detection section, and then, the  
substrate is exposed using the pattern, the position  
detection section comprising an extraction section for  
observing the mark and extracting a plurality of edge  
information of the mark in correspondence with attribute  
25 information representing features of the edge information,  
respectively, a position determination section for

comparing each edge information with one of a plurality of  
templates, which is specified by attribute information  
corresponding to the edge information and evaluating a  
plurality of comparison results obtained by comparison to  
5 determine the position of the mark, and a control section  
for changing at least one of an extraction rule in the  
extraction section and an evaluation rule in the position  
determination section on the basis of the plurality of  
comparison results by the position determination section  
10 and causing the extraction section and the position  
determination section to execute processing again.

In the exposure apparatus according to the third  
aspect of the present invention, the extraction section of  
the position detection section preferably observes the mark  
15 with an off-axis scope or TTR (Through The Reticule) or TTL  
(Through The Lens).

According to the fourth aspect of the present  
invention, there is provided an exposure apparatus  
comprising a projection optical system for projecting a  
20 pattern onto a substrate, a chuck on which the substrate  
is placed, and a position detection section for detecting  
a position of a mark on the substrate placed on the chuck,  
wherein the substrate is aligned on the basis of a detection  
result by the position detection section, and then, the  
25 substrate is exposed using the pattern, the position  
detection section comprising an extraction section for

observing the mark and extracting edge information of the mark, a position determination section for comparing the edge information with a template and evaluating a comparison result to determine the position of the mark, and a control section for changing at least one of an extraction rule in the extraction section and an evaluation rule in the position determination section on the basis of the evaluation result by the position determination section and causing the extraction section and the position determination section to execute processing again.

According to the fifth aspect of the present invention, there is provided a position detection method of detecting a position of a mark on an object, comprising the extraction step of observing the mark and extracting a plurality of edge information of the mark in correspondence with attribute information representing features of the edge information, respectively, the position determination step of comparing each edge information with one of a plurality of templates, which is specified by attribute information corresponding to the edge information and evaluating a plurality of comparison results obtained by comparison to determine the position of the mark, and the control step of changing at least one of an extraction rule in the extraction step and an evaluation rule in the position determination step on the basis of the plurality of comparison results in the position

determination step and causing the extraction step and the position determination step to execute processing again.

According to the sixth aspect of the present invention, there is provided a position detection method

5 of detecting a position of a mark on an object, comprising the extraction step of observing the mark and extracting edge information of the mark, the position determination step of comparing the edge information with a template and evaluating a comparison result to determine the position

10 of the mark, and the control step of changing at least one of an extraction rule in the extraction step and an evaluation rule in the position determination step on the basis of the evaluation result in the position determination step and causing the extraction step and the

15 position determination step to execute processing again.

Further objects, features and advantages of the present invention will become apparent from the following detailed description of the embodiments of the present invention with reference to the accompanying drawings.

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#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a flow chart of image processing in an exposure apparatus according to a preferred embodiment of the present invention;

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Figs. 2A to 2C are schematic views of exposure apparatuses according to preferred embodiments;

Fig. 3 is a view for explaining mark edge extraction processing in the preferred embodiment of the present invention;

Fig. 4A is a view showing synthesized edge portions  
5 extracted from a pre-alignment mark image;

Figs. 4B to 4E are views showing edge components (edge information) extracted from the pre-alignment mark image;

Fig. 5A is a view showing synthesized templates  
10 according to the preferred embodiment of the present invention;

Figs. 5B to 5E are views showing templates according to the preferred embodiment of the present invention; and

Figs. 6A to 6H are views showing pre-alignment marks  
15 and their step differences and video signals.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 2A is a view showing the schematic arrangement of a semiconductor exposure apparatus according to a  
20 preferred embodiment of the present invention. In this exposure apparatus, a mark for pre-alignment is detected using an off-axis scope 6.

A pattern for exposure is formed on a reticle 1. The pattern is illuminated with, e.g., an i-line or excimer  
25 laser light source of an illumination system (not shown) and projected onto a wafer 5 through a projecting lens 2.



Pre-alignment is performed after the wafer 5 is placed on a wafer chuck 4 on an X-Y stage 3 by a wafer conveyor apparatus (not shown). Since the wafer 5 is placed on the wafer chuck 4 at the accuracy depending on the conveyor apparatus, the alignment accuracy is low. Hence, accurate wafer position measurement cannot be directly started. To do this, a pre-alignment (coarse alignment) mark on the wafer is observed with the off-axis scope 6 arranged outside the projecting lens 2, the optical image of the mark is photoelectrically converted by a CCD camera 7, and then the position information of the mark is detected by a pre-alignment image processing unit 8. In the pre-alignment image processing unit 8, the photoelectrically converted video signal is converted into digital information by an A/D conversion unit 71, and the pre-alignment mark position is detected by an image processor 72 having an image memory.

It is advantageous when both the X- and Y-coordinates can be detected by one mark. For this reason, the pre-alignment mark has the same shape as that of the mark 100 shown in Fig. 6A. The position of the X-Y stage 3 when the pre-alignment mark image is captured is accurately measured by a laser interferometer 12. On the basis of the mark position shift and the position of the X-Y stage 3, a controller 9 accurately measures the shift amount of the wafer 5 placed on the chuck 4. The X-Y stage 3 is driven

by a stage driving unit 13.

In this embodiment, a case wherein dark field illumination is employed as illumination for the off-axis scope 6 will be described. In dark field illumination, scattered light from an edge position of the mark step difference is received by the CCD camera 7. The present invention can also be applied to bright field illumination.

Fig. 1 shows the flow of image processing (position detection processing) for executing pre-alignment in a position detection apparatus according to the preferred embodiment of the present invention and a semiconductor exposure apparatus using the position detection apparatus.

First, the vector correlation method (S100, S101, S102) will be described.

In step S100, the image processor 72 executes edge extraction processing for an image captured by the CCD camera 7. In edge extraction processing, both the edge information of the mark image and attribute information representing that the edge information is associated with the upper, lower, right, or left side of the mark image are simultaneously acquired.

In this embodiment, edge information (solid lines in Figs. 4B to 4E) are made to correspond to attribute information ("over", "under", "left", and "right" in Figs. 4B to 4E) and extracted for four directions of the upper, lower, left, and right sides of an actual edge of

the mark image. Edge information may be made to correspond to attribute information and acquired not only for the four directions of the upper, lower, left, and right sides of an actual edge but also for, e.g., four directions that  
5 respectively make an angle of  $45^\circ$  with the above four directions, i.e., a total of eight directions. Alternatively, edge information may be made to correspond to attribute information and acquired according to another rule.

10 In step S101, the mark image is searched on the basis of edge information and attribute information corresponding to the edge information. Searching means detection of an approximate position of the mark image. In searching the mark image, the degree of matching between  
15 the edge information extracted in step S100 and a template specified by the attribute information corresponding to the edge information is occasionally calculated while moving the template within a predetermined region, and the center coordinates of the mark (center coordinates of the  
20 template) at which the maximum degree of matching is obtained are determined. Each template is formed from feature points of interest corresponding to attribute information, to which attention must be paid in comparison with the edge information extracted from the mark image.

25 To calculate the degree of matching, the edge information (e.g., Fig. 4B) extracted in step S100 is

25           Mark position search fails in step S102 when 1) the  
          matching result (maximum degree of matching) has a value

smaller than the threshold value for detection  
determination or 2) a degree of matching equal to or higher  
than the level of threshold value for detection  
determination is obtained at a plurality of mark positions,  
5 and one of them cannot be selected.

Processing of a characteristic feature of the present  
invention starts from step S104.

If mark position search fails, the flow advances to  
the loop including step S104 to change parameters for  
10 detection, i.e., adjust one or both of the edge extraction  
processing parameter and the threshold value for detection  
determination, and edge extraction (S100), mark position  
search (S101), and detection determination (S102) are  
performed again. The repetitive loop of parameter change  
15 and search is controlled on the basis of the number of times  
or conditions set in advance. If it is determined that the  
mark position cannot be accurately detected any more even  
by repeating the repetitive loop, a detection error occurs.

Actual processing according to the flow will be  
20 described next with reference to Figs. 3 and 4A to 4E.  
First, vector correlation will be described. In edge  
extraction in step S100, scattered light from the mark 100  
is received and photoelectrically converted by the CCD  
camera 7, then A/D-converted by the A/D conversion unit 71,  
25 and stored in the image memory of the processor 72.

An image signal along a given scanning line (row) of

the stored image is represented by  $X_i$ . Since this embodiment employs dark field illumination, the image signal  $X_i$  has a certain value at the mark edge position and a value of black level at the remaining portions. A signal  
5 obtained by differentiating the image signal  $X_i$  is a differential signal  $X_{id}$ . When the scanning line is traced from the left to the right, the differential signal  $X_{id}$  becomes positive at the leading edge portion of the image signal  $X_i$  and negative at the trailing edge portion.

10 A threshold value  $thl$  is set on the positive side of the differential signal  $X_{id}$ . When the differential signal  $X_{id}$  is binarized using the threshold value  $thl$  as a reference, a left edge signal  $Le$  is obtained. In a similar way, when a threshold value  $thr$  is set on the negative side  
15 of the differential signal  $X_{id}$ , and the signal  $X_{id}$  is binarized using the threshold value  $thr$  as a reference, a right edge signal  $Re$  is obtained. The left edge signal  $Le$  represents the left edge position of the mark image, and the right edge signal  $Re$  represents the right edge position  
20 of the mark image. When the above processing is executed for all scanning lines, pieces of edge information representing the left edge positions of the mark image and pieces of edge information representing the right edge positions are obtained.

25 An image signal along a vertical line (column) on the image memory is represented by  $Y_i$ . Like the image signal

Xi, the image signal Yi is traced from the lower side to the upper side, and a differential signal Yid is generated. When the differential signal Yid is binarized using threshold values  $\text{thu}$  and  $\text{tho}$ , an under edge signal Ue and over edge signal Oe are obtained. The under edge signal Ue represents the under edge position of the mark image, and the over edge signal Oe represents the over edge position of the mark image. When the above processing is executed for all vertical lines, pieces of edge information representing the under edge positions of the mark image and pieces of edge information representing the over edge positions are obtained.

In Fig. 4A, edge information representing the right edge positions, edge information representing the left edge positions, edge information representing the over edge positions, and edge information representing the under edge positions all of the mark 100 are synthesized and two-dimensionally illustrated. In this embodiment, as edge position images (edge information and attribute information), edge information associated with attribute information "over" shown in Fig. 4B, edge information associated with attribute information "under" shown in Fig. 4C, edge information associated with attribute information "left" shown in Fig. 4D, edge information associated with attribute information "right" shown in Fig. 4E are stored in the processor 72 as independent

information.

Mark image search (S101) is performed by matching calculation of templates stored in advance and edge position images (edge information) shown in Figs. 4B to 4E.

5 Figs. 5A to 5E are views for explaining the templates.

Since the positions of the over, under, left, and right edges relative to the mark center (cross) are known, the templates are registered as layouts shown in Figs. 5B to 5E in which feature portions of the mark are indicated by open circles. That is, the templates can be determined on the basis of the shape of the mark to be formed on the wafer. Fig. 5A shows the synthesized image of the four registered templates shown in Figs. 5B to 5E. In this embodiment, the position of an open circle is called a feature point of interest, and a set of points of interest is called a template. In each template of this embodiment, feature points of interest are defined on only one side edges of the mark. For example, in the template shown in 10 Fig. 5B, the feature points of interest are defined on only the over edges of the mark.

Matching calculation in mark image search is performed by determining whether, e.g., the pieces of edge information shown in Fig. 4B are present at the positions of open circles in Fig. 5B with reference to the mark center 15 (cross). In a similar way, Fig. 4C and Fig. 5C, Fig. 4D



and Fig. 5D, and Fig. 4E and Fig. 5E are compared to  
determined whether the pieces of edge information shown in  
Figs. 4C to 4E are present at the position of open circles  
in Figs. 5C to 5E, respectively. When the edge information  
5 are present at all the hollow bullet positions, the degree  
of matching is 100%. If some hollow bullet positions have  
no edge information, the degree of matching is lower than  
100%. The above matching calculation is performed for the  
entire edge images while changing the mark center  
10 coordinates, and mark center coordinates at which the  
degree of matching is highest are finally extracted,  
thereby completing the search.

The feature points of interest shown in Figs. 5B to  
5E are defined by thinning out points and designating two  
15 points that define specific edges. Even when the number  
of feature points of interest is increased, no effect is  
obtained unless they express the characteristic feature of  
the mark shape. If the feature points of interest are  
densely defined, the degree of matching becomes low due to  
20 various reasons, and the mark image may not be detected.  
Especially, when the mark is damaged, the degree of matching  
often extremely lowers. For this reason, a high detection  
rate can be stably obtained by setting thinned out feature  
points of interest, as described above.

25 Vector correlation has been described above.

When the maximum degree of matching obtained by the

above-described search is lower than the level of threshold value for determination, the coordinates at which the maximum degree of matching is obtained may not indicate the correct mark position. In this case, edge information  
5 extraction may be not optimum. Hence, preferably the threshold values thl, thr, thu, and tho used for extraction of mark edge information are corrected, the edge information are generated again, and search is repeated.

For example, when the threshold values thl, thr, thu,  
10 and tho for edge extraction are originally relatively large, no edge information is obtained from a low-contrast mark image. Hence, the degree of matching in search is low, and mark detection determination is impossible. Preferably, the edge information of the mark is detected while gradually  
15 decreasing the threshold value for edge extraction. This makes it possible to obtain a sufficient degree of matching in search.

As another example, when there are a plurality of coordinates at which a degree of matching higher than the  
20 level of threshold value for determination, the mark position cannot be determined. In this case as well, the mark position can be reliably determined by increasing the determination threshold value and repeating edge information generation and search.

25 The position detection parameter such as the threshold value for edge extraction or threshold value for

determination can be efficiently changed by storing, e.g., a value determined according to the immediately preceding search processing result (degree of matching) in the memory and using the value as the base (e.g., initial value) for  
5 detection parameter determination of the next time.

For precise detection (S103) after the end of mark image search, the mark position can be determined at an accuracy beyond the pixel resolution by, e.g., a method of obtaining the barycenter on the basis of the luminance  
10 distribution with an origin set at the center coordinates of the A/D-converted image found by the search.

In this embodiment, edge extraction is performed immediately after image reception. Processing of performing noise removal filtering before edge extraction  
15 to lower the noise level in advance and prevent any unnecessary edge information, or forming a bold line image as edge information to correct deformation in mark size or omission of edges is also effective. Processing of  
adjusting the noise removal parameter or bold line  
20 formation parameter is also effective. Addition of the above processing results in an increase in detection rate in mark search.

In the first embodiment, the position detection apparatus of the present invention and the semiconductor  
25 exposure apparatus using the position detection apparatus are applied to pre-alignment using the off-axis scope 6.

However, the processing of mark position search is not limited to pre-alignment using off-axis.

Fig. 2B shows the second embodiment in which the position detection apparatus of the present invention is applied to a TTR detection system for detecting a mark on a wafer 5 or stage through a reticle 1 in a semiconductor exposure apparatus.

To detect a mark in the TTR detection system, exposure light is used. For example, in a semiconductor exposure apparatus using an excimer laser, a CCD camera 7 and laser 21 are synchronized by a sync signal generator 20 to emit a laser beam only during the light storage time of the CCD camera 7. For the photoelectrically converted mark image, the mark position search is done by the same method as in the first embodiment, and after the search, an accurate mark position can be calculated. In an i-line exposure apparatus, since the light source is not a laser, synchronization between image reception and the illumination system is unnecessary. For this reason, the mark position search can be done, and accurate mark position calculation can be performed after the search, as in the first embodiment.

In reticle alignment for alignment the reticle 1 with respect to a projecting lens 2 as well, the same processing as in the first embodiment can be performed for a mark search.

Fig. 2C shows the third embodiment of the present invention in which the position detection apparatus of the present invention is applied to a TTL detection system for detecting the mark position on a wafer 5 or stage 3 through a projecting lens 2 without interposing a reticle 1 in a semiconductor exposure apparatus. In TTL as well, the mark search and position determination can be performed by the same method as that of the first embodiment except that the mark image sensing method is different.

As has been described above, in the position detection apparatus according to the preferred embodiment of the present invention and the semiconductor exposure apparatus using the position detection apparatus, the edge information of a mark image is extracted in correspondence with attribute information, the edge information is compared with a corresponding template in units of partial edges on the basis of the attribute information, and the obtained comparison result is evaluated, thereby determining the mark position. Since it can be determined at high probability in units of partial edges whether a partial edge (e.g., Fig. 4B) and a template (e.g., Fig. 5B) corresponding to the edge match, the probability of mark position detection becomes higher than that of the prior art in which it is determined whether the entire mark image matches the template. Hence, according to this embodiment, the position of the image of a mark with degradation or a

defect generated in manufacturing a high-density semiconductor device, e.g., a low-contrast mark image, a noisy mark image, or a mark image obtained by sensing a defect generated in the wafer process can be more stably  
5 detected.

As a consequence, in this position detection apparatus and semiconductor exposure apparatus using the position detection apparatus, by repeating pattern matching while adjusting one or both of the edge extraction  
10 parameter and parameter used to determine the matching result in accordance with the result of template matching, the image of a mark with degradation or a defect can be more reliably detected.

The present invention is not limited to the above  
15 embodiments and various changes and modifications can be made within the spirit and scope of the present invention. Therefore, to apprise the public of the scope of the present invention, the following claims are made.

WHAT IS CLAIMED IS:

1. A position detection apparatus for detecting a position of a mark on an object, comprising:

an extraction section for observing the mark and  
5 extracting a plurality of edge information of the mark in correspondence with attribute information representing features of the edge information, respectively;

a position determination section for comparing each edge information with one of a plurality of templates, which  
10 is specified by attribute information corresponding to the edge information and evaluating a plurality of comparison results obtained by comparison to determine the position of the mark; and

a control section for changing at least one of an  
15 extraction rule in said extraction section and an evaluation rule in said position determination section on the basis of the plurality of comparison results by said position determination section and causing said extraction section and said position determination section to execute  
20 processing again.

2. The apparatus according to claim 1, wherein each attribute information represents an edge portion of the mark, which is associated with the corresponding edge information.

25 3. The apparatus according to claim 1, wherein each attribute information represents one of a plurality of

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extraction conditions under which the corresponding edge information is extracted.

4. The apparatus according to claim 1, wherein said extraction section extracts, as each edge information, information representing an edge position shifted from an actual edge position of the mark by a predetermined distance in one of a plurality of predetermined directions, and each attribute information represents a direction in which an edge position associated with the corresponding edge information shifted from the actual edge position of the mark by the predetermined distance.

5. The apparatus according to claim 1, wherein said extraction section comprises:

an image sensing section for sensing an image of the mark;

a differential processing section for differentiating the mark image as an image sensing result; and

an edge information generation section for processing the differential result to generate the edge information corresponding to the attribute information.

6. The apparatus according to claim 5, wherein said differential processing section calculates a change rate of an image signal of the mark image along at least two directions of the mark image, and

each attribute information is associated with one of





the extracted edge information.

13. The apparatus according to claim 1, wherein the extraction rule and/or the evaluation rule determined by said control section is stored in a memory and used as a  
5 base for processing to be executed later.

14. The apparatus according to claim 1, wherein said extraction section observes the mark under dark field illumination.

15. A position detection apparatus for detecting a  
10 position of a mark on an object, comprising:

an extraction section for observing the mark and extracting edge information of the mark;

a position determination section for comparing the edge information with a template and evaluating a  
15 comparison result to determine the position of the mark; and

a control section for changing at least one of an extraction rule in said extraction section and an evaluation rule in said position determination section on  
20 the basis of the evaluation result by said position determination section and causing said extraction section and said position determination section to execute processing again.

16. An exposure apparatus comprising:  
25 a projection optical system for projecting a pattern onto a substrate;

a chuck on which the substrate is placed; and  
a position detection section for detecting a position  
of a mark on the substrate placed on said chuck,

wherein the substrate is aligned on the basis of a  
5 detection result by said position detection section, and  
then, the substrate is exposed using the pattern,

said position detection section comprising:

an extraction section for observing the mark and  
extracting a plurality of edge information of the mark in  
10 correspondence with attribute information representing  
features of the edge information, respectively;

a position determination section for comparing each  
edge information with one of a plurality of templates, which  
is specified by attribute information corresponding to the  
15 edge information and evaluating a plurality of comparison  
results obtained by comparison to determine the position  
of the mark; and

a control section for changing at least one of an  
extraction rule in said extraction section and an  
20 evaluation rule in said position determination section on  
the basis of the plurality of comparison results by said  
position determination section and causing said extraction  
section and said position determination section to execute  
processing again.

25 17. The apparatus according to claim 16, wherein said  
extraction section of said position detection section

observes the mark with an off-axis scope.

18. The apparatus according to claim 16, wherein said extraction section of said position detection section observes the mark by TTR (Through The Reticle).

5 19. The apparatus according to claim 16, wherein said extraction section of said position detection section observes the mark by TTL (Through The Lens).

20. The apparatus according to claim 16, wherein each attribute information represents an edge portion of the  
10 mark, which is associated with the corresponding edge information.

21. The apparatus according to claim 16, wherein each attribute information represents one of a plurality of extraction conditions under which the corresponding edge  
15 information is extracted.

22. The apparatus according to claim 16, wherein said extraction section extracts, as each edge information; information representing an edge position shifted from an actual edge position of the mark by a predetermined distance  
20 in one of a plurality of predetermined directions, and each attribute information represents a direction in which an edge position associated with the corresponding edge information shifted from the actual edge position of the mark by the predetermined distance.

25 23. The apparatus according to claim 16, wherein said extraction section comprises:

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an image sensing section for sensing an image of the mark;

a differential processing section for differentiating the mark image as an image sensing result;

5 and

an edge information generation section for processing the differential result to generate the edge information corresponding to the attribute information.

24. The apparatus according to claim 23, wherein said  
10 differential processing section calculates a change rate of an image signal of the mark image along at least two directions of the mark image, and

each attribute information is associated with one of the at least two directions.

15 25. The apparatus according to claim 23, wherein each attribute information is associated with a sign of the differential result by said differential processing section.

26. The apparatus according to claim 24, wherein each  
20 attribute information is associated with a sign of the differential result by said differential processing section.

27. The apparatus according to claim 23, wherein said  
25 differential processing section calculates a change rate of an image signal of the mark image across the mark image along row and column directions of the mark image, and

each attribute information is associated with one of the row and column directions and the differential result by said differential processing section.

28. The apparatus according to claim 16, wherein each  
5 template includes, as information to be compared with the edge information, position information of a plurality of points defining a corresponding edge.

29. The apparatus according to claim 16, wherein each  
10 template includes, as information to be compared with the edge information, position information of points on a continuous line defining a corresponding edge.

30. The apparatus according to claim 16, wherein said  
15 extraction section performs noise removal processing for an observation result of the mark and then executes edge information extraction.

31. The apparatus according to claim 16, wherein said  
extraction section increases a line width associated with the extracted edge information.

32. The apparatus according to claim 16, wherein the  
20 extraction rule and/or the evaluation rule determined by said control section is stored in a memory and used as a base for processing to be executed later.

33. The apparatus according to claim 16, wherein said  
25 extraction section observes the mark under dark field illumination.

34. An exposure apparatus comprising:

a projection optical system for projecting a pattern onto a substrate;

a chuck on which the substrate is placed; and

a position detection section for detecting a position  
5 of a mark on the substrate placed on said chuck,

wherein the substrate is aligned on the basis of a detection result by said position detection section, and then, the substrate is exposed using the pattern,

said position detection section comprising:

10 an extraction section for observing the mark and extracting edge information of the mark;

a position determination section for comparing the edge information with a template and evaluating a comparison result to determine the position of the mark;

15 and

a control section for changing at least one of an extraction rule in said extraction section and an evaluation rule in said position determination section on the basis of the evaluation result by said position  
20 determination section and causing said extraction section and said position determination section to execute processing again.

35. A position detection method of detecting a position of a mark on an object, comprising:

25 the extraction step of observing the mark and extracting a plurality of edge information of the mark in

correspondence with attribute information representing features of the edge information, respectively;

the position determination step of comparing each edge information with one of a plurality of templates, which  
5 is specified by attribute information corresponding to the edge information and evaluating a plurality of comparison results obtained by comparison to determine the position of the mark; and

the control step of changing at least one of an  
10 extraction rule in the extraction step and an evaluation rule in the position determination step on the basis of the plurality of comparison results in the position determination step and causing the extraction step and the position determination step to execute processing again.

15 36. A position detection method of detecting a position of a mark on an object, comprising:

the extraction step of observing the mark and extracting edge information of the mark;

the position determination step of comparing the edge  
20 information with a template and evaluating a comparison result to determine the position of the mark; and

the control step of changing at least one of an extraction rule in the extraction step and an evaluation rule in the position determination step on the basis of the  
25 evaluation result in the position determination step and causing the extraction step and the position determination



step to execute processing again.

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ABSTRACT OF THE DISCLOSURE

A plurality of edge information of a mark are  
extracted together with attribute information that  
represents the shift direction of the edge information from  
5 the actual edge position of the mark, i.e., one of the over,  
under, left, or right directions. The plurality of edge  
information are compared with templates specified by  
corresponding attribute information. The mark position is  
detected on the basis of a plurality of comparison results  
10 obtained by comparison.

FIG. 1

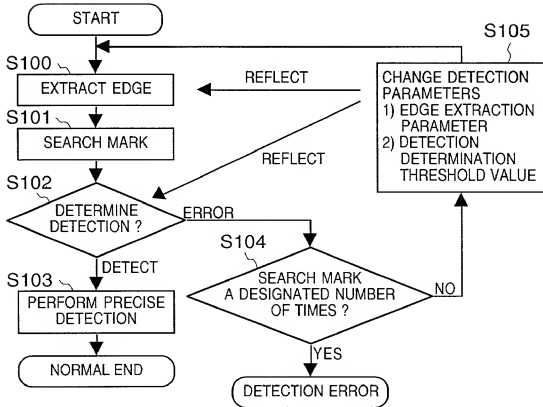
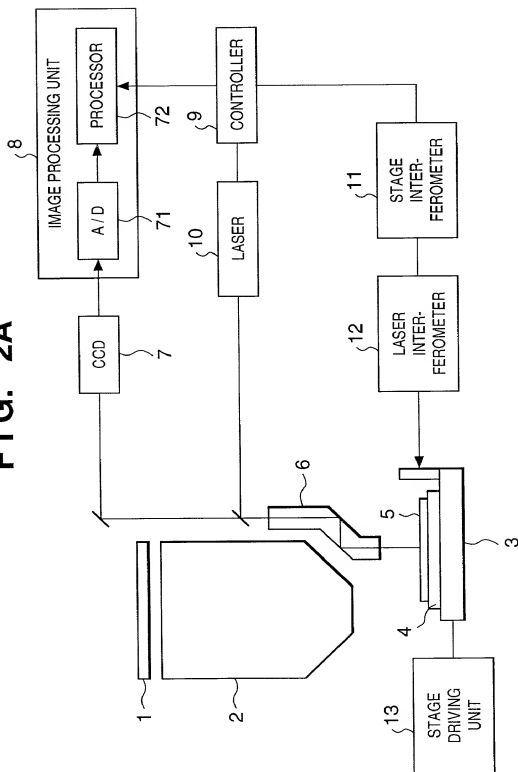


FIG. 2A



**FIG. 2B**

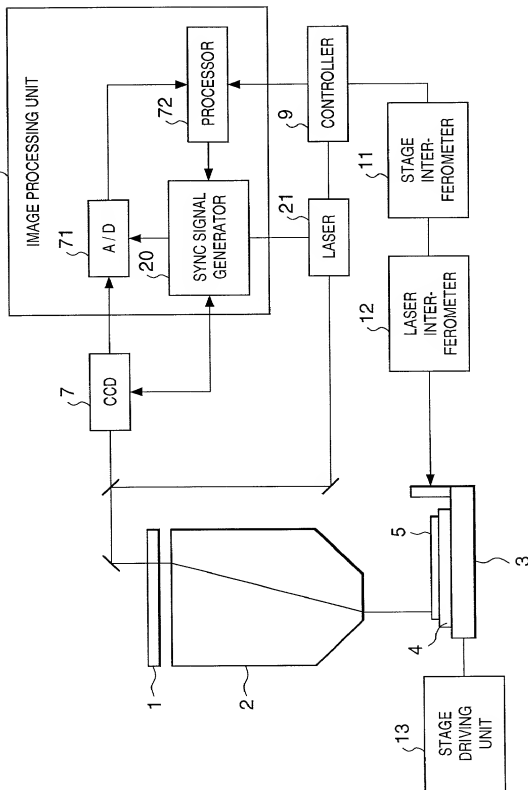
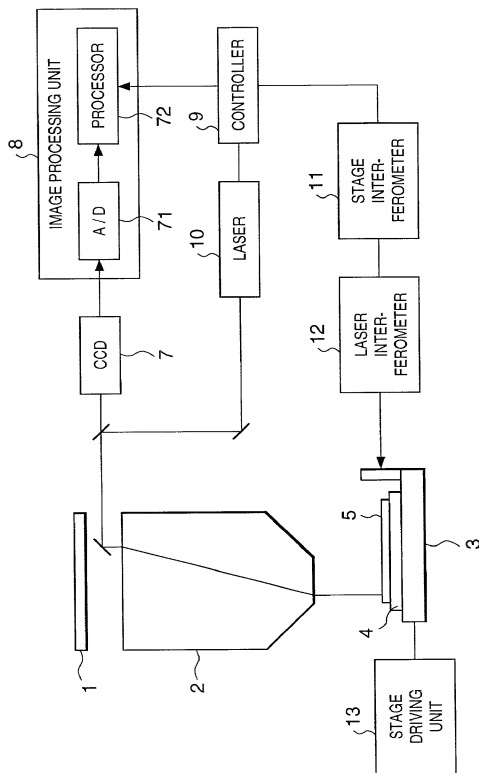
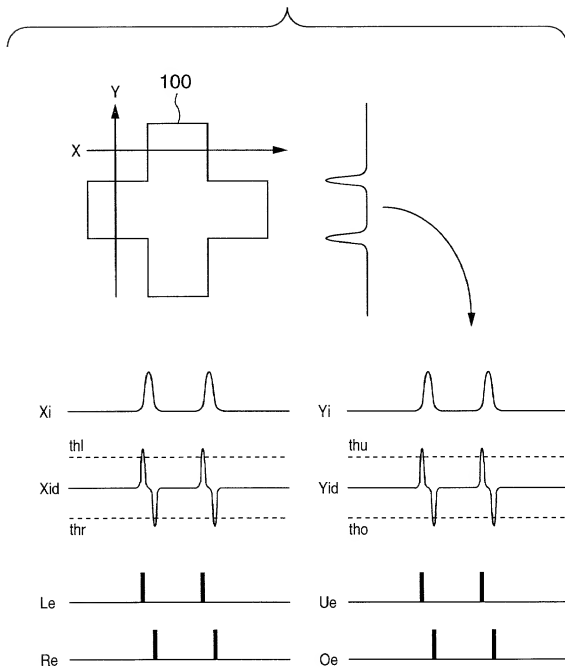
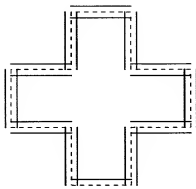


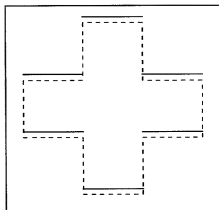
FIG. 2C



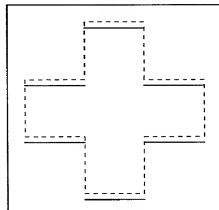
**FIG. 3**

**FIG. 4A****FIG. 4B**

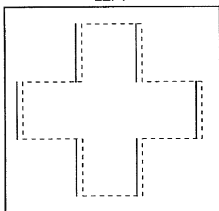
OVER

**FIG. 4C**

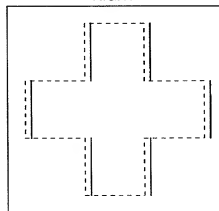
UNDER

**FIG. 4D**

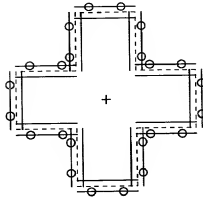
LEFT

**FIG. 4E**

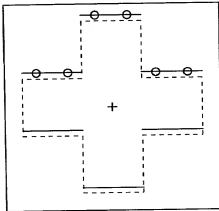
RIGHT



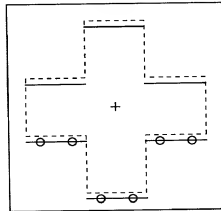


**FIG. 5A****FIG. 5B**

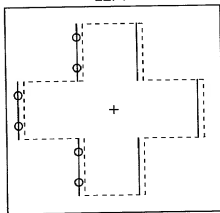
OVER

**FIG. 5C**

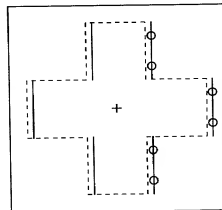
UNDER

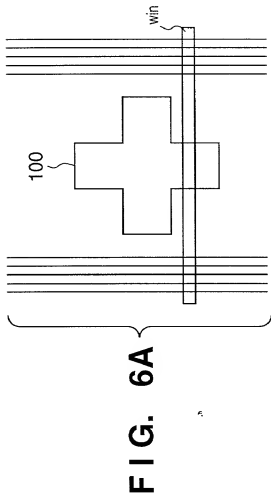
**FIG. 5D**

LEFT

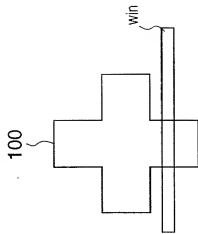
**FIG. 5E**

RIGHT

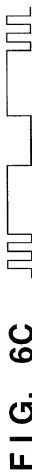




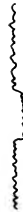
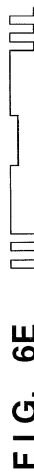
**FIG. 6F**



**FIG. 6G**



**FIG. 6H**



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**COMBINED DECLARATION AND POWER OF ATTORNEY  
FOR PATENT APPLICATION**  
(Page 1)

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name;

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

POSITION DETECTION APPARATUS AND EXPOSURE APPARATUS

the specification of which [X] is attached hereto. [ ] was filed on \_\_\_\_\_

as United States Application No. or PCT International Application No. \_\_\_\_\_  
and was amended on \_\_\_\_\_ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR §1.56.

I hereby claim foreign priority benefits under 35 U.S.C. §119(a)-(d) or §365(b), of any foreign application(s) for patent or inventor's certificate, or §365(a) of any PCT international application which designates at least one country other than the United States, listed below and have also identified below any foreign application for patent or inventor's certificate, or PCT international application having a filing date before that of the application on which priority is claimed:

<u>Country</u>	<u>Application No.</u>	<u>Filed (Day/Mo./Yr.)</u>	<u>(Yes/No)</u> <u>Priority Claimed</u>
JAPAN	11-062004	09/03/1999	Yes

I hereby appoint the practitioners associated with the firm and customer number provided below to process this application and to transact all business in the Patent and Trademark Office connected therewith, and direct that all correspondence be addressed to the address associated with that Customer Number:

**FITZPATRICK, CELLA, HARPER & SCINTO**  
Customer Number: 05514

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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